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Foreword

The Agricultural Technology Development and Transfer Collaborators Workshop, on which these proceedings are based, was organized by the U.S. Agency for International Development, Africa Bureau, Office of Sustainable Development, Productive Sector Growth and Environment Division (USAID/AFR/SD/PSGE).* The workshop provided an opportunity to review the analytical activities that SD/PSGE's Technology Development and Transfer (TDT) Unit is undertaking.

Intended to be an annual meeting, the workshop was particularly important because it provided a venue for the development community to discuss and influence the direction of the TDT agenda supported by the Africa Bureau. A clear outcome of the workshop is a growing consensus that:

- agricultural technology development and transfer is necessary for sustainable economic growth;
- past investments have made significant economic contributions to the improved welfare of the current generation of Africans;
- institutional constraints are a key factor limiting the impact of technology systems in Africa; and
- new partnerships, including increased involvement of the private sector, will be important for sustainable technology initiatives in Africa.

In the next several years, these proceedings will be particularly useful in helping to strategically guide and cross-check progress of the TDT analytical agenda for the Africa Bureau and USAID in general. This synthesis document has been designed specifically to reflect the heart of the issues discussed and recommendations emerging from the workshop. It is not an itemized proceedings of each paper. The list of papers and presentations are summarized in Annex 2.

I would like to acknowledge the role that Cheryl Christensen, from U.S. Department of Agriculture's Economic Research Service, played in organizing the workshop and drafting this synthesis report. I would also like to thank the many participants that traveled from across the United States, Europe, and Africa to participate in this workshop. The experience and insights they brought greatly enriched the workshop's dialogue and outcome.

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* Formerly the Office of Analysis, Research, and Technical Support / Division of Food, Agriculture, and Resources Analysis (USAID/AFR/ARTS/FARA).

Glossary of Abbreviations and Acronyms

AARC	Alternative Agricultural Research and Commercialization (USDA term)
AIRD	Associates for International Resources and Development
AFR	Bureau for Africa (USAID)
ARS	Agricultural Research Service (part of USDA)
ART	Agricultural Research Trust (Zimbabwe)
ARTS/FARA	Office of Analysis, Research, and Technical Support / Division of Food, Agriculture, and Resources Analysis (USAID/AFR, now SD/PSGE)
CFA franc	unit of currency used by the Francophone, 14-state African Financial Community
CGIAR	Consultative Group for International Agricultural Research
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo (Center for International Maize and Wheat Improvement)
CIP	International Potato Center
CIRAD	Center de Coopération Internationale en Recherche Agronomique pour la Développement
CRSP	Collaborative Research Support Program
DESFIL	Development Straties for Fragile Lands Project
IARC	international agricultural research center
IFDC	International Fertilizer Development Center
IITA	International Institute of Tropical Agriculture
INSAH	Sahel Institute
ISNAR	International Service for National Agricultural Research
KARI	Kenyan Agricultural Research Institute
MSU	Michigan State University
NARS	national agricultural research system(s)
NGO	nongovernmental organization
SAFGRAD	Semi-Arid Food Grain Research and Development Project
SD/PSGE	Office of Sustainable Development / Productive Sector Growth and Environment Division (USAID/AFR, formerly ARTS/FARA)
SPAAR	Special Program for African Agricultural Research
TAC	technical advisory committee
TDT	Technology development and transfer
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
WARDA	West African Rice Development Authority

Executive Summary

More than 75 people participated in the Agricultural Technology Development and Transfer (TDT) Collaborators Workshop, held June 28–30, 1993, in Washington, D.C. Participants included representatives from international research centers, U.S. universities, African public research institutes, the World Bank, the Special Program for African Agricultural Research (SPAAR), and U.S. Agency for International Development (USAID) field and Washington offices. The workshop was sponsored by the USAID Africa Bureau's Office for Sustainable Development, Productive Sector Growth and Environment Division (AFR/SD/PSGE).

The workshop catalyzed new awareness of agriculture's key role in economic development and of the critical roles that technology development and dissemination play in actualizing this vision, as participants sessions assessed the impact and availability of agricultural technology, as well as the institutional structures within which technology is developed and disseminated. The primary outputs of the workshop were (*a*) identification of four primary findings and (*b*) consensus on four priority issues to be addressed in both USAID's technology development and transfer activities and the related activities of International Agricultural Research Centers (IARCs), National Agricultural Research Systems (NARSs), and donors.

Primary Findings

1. *Agricultural Research Pays Off.* Recent studies show that agricultural research made substantial contributions to increased growth and income in Africa in the 1980s, despite that decade's policy distortions, economic crisis, and high population growth rates. Current moves toward policies more favorable to market-oriented growth offer hope for significant gains if effective technologies are developed and disseminated.

2. *Markets Matter*. Successful technology adoption occurs when there are functioning local, national, or international markets into which increased output can be sold, generating increased employment and income in the agricultural and nonagricultural sectors.

3. *Technologies Exist—But Not Enough.* Available technologies can increase agricultural productivity significantly and can be adopted by producers, marketing agents, and processors in response to changing economic conditions and emerging market opportunities. However, these technologies do not address all key constraints—for example, in environmental management and sustainability—and they apply to differing time frames. Thus, continued investment in technology development and transfer is essential.

4. *Institutions in Crisis.* The research institutions that must be the bedrock for any initiatives to develop and disseminate technologies to support sustainable growth are themselves facing serious funding, management, and personnel problems. Developing effective, sustainable agricultural research systems is the major challenge for Africans, the donors and the IARCs.

Priority Issues

1. *Priority Setting.* Many African TDT institutions have too many programs, with their resources spread too thinly to achieve high quality, sustainable programs. Better mechanisms are needed for priority setting that involves both decisions about the relative payoff of alternative research approaches and about the mandate of public research institutions. Workshop participants concluded that **increased attention should be given to priority setting for TDT investments** that help to:

   - select topics, commodities, and cross-commodity themes in the regional and national context to support agricultural transformation and sustainable growth;
   - give attention to elimination of binding constraints (production, marketing, processing) within a subsector;
   - support technologies with promising impacts on incomes, food security, and environmental sustainability; and
   - foster linkages among national, regional, and international research systems.

2. *Enabling Environment for Sustainable Research Systems.* Over the next decade, a sustainable financial and institutional base must be developed to support the investments in human capital made over the last decade. The NARSs are the building blocks for sustainable research systems in Africa, but they face constraints such as weak financial management systems, obsolete public statutes, and difficulties linking research with market and development challenges. Workshop participants encouraged **the establishment of an enabling environment for African scientists to improve the efficiency and sustainability of regional and national agricultural systems.** Establishing an enabling environment would involve:

   - reforming research and policy institutions;
   - creating financially sustainable funding mechanisms; and
   - developing and sustaining human resource capacity.

3. *Research Systems for the 21st Century.* Research systems for in Africa must be made more demand driven, enabling them to respond to market demands with profitable and sustainable technologies that support economic development. Demand-driven systems require openness to diverse interests in the agricultural system and the capacity to maintain continuity while integrating new demand-driven research thrusts into the research agenda. African research systems must also (*a*) develop new capabilities to develop and disseminate technologies to support environmental sustainability; (*b*) establish effective regional cooperation to support more open, environmentally focused research institutions; and (*c*) effectively link African research systems into the rapidly changing global research network. Workshop participants encouraged the **development of research systems and technologies for the first decade of the 21st century**, including attention to:

   - achieving balance between productivity and conservation;
   - increasing pluralism in development by reaching a more diverse clientele;
   - regionalization; and
   - identifying new technology needs.

4. *Commercialization and Transfer of Technology.* Ways must be found to make technology development and transfer more results-oriented so that researchers have incentives and mechanisms to transfer profitable and sustainable technologies. Establishing new incentives may involve altering

institutional norms or changing policies and legal practices to facilitate commercialization. Workshop participants encouraged **increased attention to the transfer of known and emerging technologies**, through:

- commercializing technologies and improving the enabling environment for this to happen;
- increasing the involvement of nongovernmental organizations and private and public sector institutions in the dissemination of technologies and information regarding them; and
- improving mechanisms for exchanging technologies among regions and countries.

1. Background

1.1. Justification

Agricultural technology development and transfer (TDT) in Africa faces unique challenges that call for a significant, sustained effort to build a 21st century research system that looks different from the institutional models provided by other regions or earlier time periods. The stakes involved in this effort are high—both for the growth potential of African economies and for the well-being of millions of people who depend on agriculture for their lives and livelihood. Productivity increases are vital to agricultural growth, which is in turn critical to economic development. Recent evidence shows that research and TDT are able to "deliver the goods," even in less than perfect conditions. Technologies exist that have made significant people-level impacts in many countries. More are under development. The biggest challenge now is to create sustainable and effective research systems that can catalyze agricultural transformation in this century and the next. The imperative of this challenge, and the issues that need to be addressed to meet it, are the primary focus of the workshop and these proceedings.

1.1.1. Importance of Agriculture in Economic Development

Agriculture is important to Africa's development for two main reasons:

- it is a major current source of employment, food security, foreign exchange, and raw materials;
- it can make a powerful contribution to economic transformation and sustainable growth.

In his keynote address, Edward Jaycox, vice president for Africa at the World Bank, highlighted the importance of the agriculture sector in supporting economic growth and sustainable development in Africa. To achieve modest growth in income and employment, the Bank projects that African economies will need to grow 4 to 5 percent per annum over the next decade. The primary source of growth can only be agricultural production—which the Bank targets to increase by 4 percent per year. Such output growth requires substantial gains in productivity.

Sustainable development in Africa will require the increased use of profitable and sustainable agricultural technology to help farmers, processors, marketing agents, and policy makers address on and off farm constraints and to accelerate agricultural transformation. The flow of technology to and within Africa to meet future needs will require an enabling environment that promotes the collaborative efforts of public and private national, regional and international organizations. The supply of technology will need to be sharply focused on themes and commodities with the prospects for broad based improvements in income and food security. These efforts must be led and supported by Africans.

Agricultural transformation—the process by which agriculture shifts from being dominated by highly diversified, subsistence-oriented production toward more specialized production dependent on markets—is itself a powerful catalyst for wider economic development. Economic development is generally fueled by resource transfers from agriculture to other sectors of the economy. Increased agricultural productivity is the most effective way to generate these

resources. (The alternative, government intervention to extract resources, has harmed both agriculture and economic growth in many African countries.) Policy reforms that support the growth of markets will be difficult to sustain without agricultural productivity increases. TDT is key to increasing such productivity.

1.1.2. Unique African TDT Challenge

African agricultural research institutions face a number of unique challenges and constraints that cry out for regional approaches. First, while there is considerable unevenness across countries, many national agricultural research systems (NARS) in Africa are relatively small. The countries they serve often have diverse production patterns, unlike countries in Asia where a single dominant crop (e.g., rice) helps focus research priorities. Resources are limited. In this environment, focusing on priorities is key. National systems cannot achieve excellence in all areas.

The heterogeneous nature of African production systems also creates unique difficulties as well as promising alternatives. Diverse production systems, sensitive to local climatic and environmental conditions, make it more difficult to develop "generic" technological packages. Defining the recommendations domains for new technologies is more challenging and may spill rather significantly across national boundaries. Here regional research initiatives—organized around ecoregional zones—can provide both economies of scale and "better science."

A third feature of the African countries is that, for the most part, their agricultural economies are in any earlier stage of development than most countries in Asia or Latin America; and perhaps at an earlier stage than those countries were when their research systems were established. Agricultural transformation is just beginning in many African countries. This creates a unique challenge of integrating the research system into the initial stages of agricultural transformation in a way that contributes directly to economic growth and improved people-level impact.

Fourth, the research institutions in Africa are new institutions, but institutions whose legacy is old. Many institutions were developed at a time when government control of the economy was the dominant mode. They also developed in periods when political pluralism was limited, and agricultural interests—whether at the production or the processing level—were poorly organized and ill-defined. These institutions now face economic reform that reduces government resources and increases the role of market-driven economies. As reform cutbacks shrink government budgets, the funding available to support agricultural research also dwindles. Thus, the institutional management put in place before reforms needs to be realigned with the realities of adjustment—increased market-orientation and financial limitations. This is happening in other parts of the world as well, but the challenge is more dramatic in Africa. Institutional structures need to develop quickly in this economically harsh environment for reform to succeed.

Finally, civil unrest remains prevalent in large parts of Africa. This complicates the process of TDT. Waiting for stability before initiating TDT programs is not an option. Instead, the current situation must be faced realistically while attempting to build institutions that are as resilient as possible and forge linkages that can both produce benefits and limit damage. Regional networks can provide some capacity to cope with these uncertainties by providing mechanisms for preserving research assets (e.g., germplasm and professional expertise) in times of civil strife, and providing a basis for limited efforts in countries unable to support research programs.

1.2. Objectives of the Report

Within the USAID Africa Bureau's Office of Analysis, Research, and Technical Support,

Division of Food, Agriculture, and Resources Analysis (ARTS/FARA) the TDT unit's analytical agenda responds to Africa's unique TDT challenges (see figure 1). It is generating and making available information and analytic tools to improve understanding of TDT impacts and issues to a range of institutions involved in TDT. Important clientele include USAID's mission and Washington staff, other donors involved in TDT activities, and the African research institutions themselves. Better knowledge of research returns and impacts will help all of these institutions better assess their TDT activities. In addition, the identification of key elements of the "institutional crisis" in African TDT and the development of analytic approaches to them will help provide a level playing field in which institutions have better knowledge of what is available to them as they address these issues in their own national and regional environments.

The workshop was designed to provide an intellectual "vetting" of the ARTS/FARA/TDT analytic agenda. Workshop participants were was asked to provide feedback on the agenda and, more importantly, to identify and thoroughly discuss issues important to USAID's ongoing commitment to TDT in Africa. The workshop was a forum for good professional discussion of the substance of the issues. It did not focus on the implementation of the agenda per se.

In synthesizing the results of presentations and group discussions at the Agricultural Technology Development and Transfer Collaborators Workshop, the current document has two objectives:

- to summarize and interpret the evidence presented on TDT in support of sustainable

Figure 1. TDT Analytical Activity Summary

TDT Objective: Assist Missions and the Africa Bureau to Revitalize African Agricultural Research to Develop and Transfer Sustainable and Profitable Technology

ANALYTICAL THEME:	1. Demand and Supply of Technology	2. Policy and Institutional Environment for TDT	3. Performance Monitoring and Impact Assessment
ANALYTICAL ACTIVITY	■ Strategic Framework for Technology Development and Transfer ■ Regional Research Networks (East Africa: potato and sweet; agroforestry, beans, cassava)	■ Framework for Action ■ TDT Case Studies on Public-Private Collaboration ■ Intellectual Property Rights	■ Rate-of-Return Studies (completed 9/93) ■ Impact Symposium (completed 10/92) ■ Maize Research Impacts (completed) ■ SAFGRAD Impact Assessment
ANALYTICAL ACTIVITY	■ Technological Frontiers ■ Regional Research Networks (West and Central Africa: maize, sorghum, rice)	■ Institutional and Policy Reform of Regional and National Research Systems	■ Priority Setting and Economic Impact Assessment (West and Central Africa; East Africa; Southern Africa)

development; and

- to identify key analytic issues to be addressed as part of USAID's continuing commitment to promote TDT in Africa.

2. Empirical Findings

2.1. Agricultural Research Pays Off

Contrary to "conventional wisdom," African agricultural research is a good investment with high rates of return. Recent studies show that agricultural research made substantial contributions to increased growth and income in Africa in the 1980s, during a time when policy distortions, economic crisis, and high population growth rates created a difficult climate for technology development and dissemination. Current moves toward policies more favorable to market-oriented growth offer hope for significant gains if effective technologies are developed and disseminated.

A collection of eight studies conducted by Michigan State University between 1990–1992 found that TDT was a good investment; its benefits significantly exceed its costs. The studies estimated the rate of return on TDT investments. "The rate of return summarizes the benefits, costs and time frame of the TDT activity in a single number, which is easily compared to interest rates or other measures of the cost of obtaining funds." Positive rates were established for maize in Kenya, Zambia, and Mali, and for cowpea in Senegal and Cameroon. Positive rates of return ranged from 3 percent (cowpea in Cameroon) to 135 percent (maize in Mali). The Semi-Arid Food Grain Research and Development Project (SAFGRAD) evaluation similarly found high rates of return for maize in Ghana (74 percent).

Biocontrol of the cassava mealy bug has been a major TDT success story. The 1980s threatened cassava production across much of sub-Saharan Africa. The International Institute of Tropical Agriculture (IITA) developed a biocontrol program based on the release of a parasitic wasp from South America. The program was extremely effective. The program is credited with saving cassava as a crop in Africa—thus staving off a potentially catastrophic decline in this drought-resistant staple crop. The program was also an extremely good investment, with a rate of return estimated at 143 percent. (See box, "Biocontrol for Africa.")

Improved mangrove swamp rice varieties developed by the West Africa Rice Development Authority (WARDA) have also led to demonstrable impacts. The varieties have yields of 25 to 32 percent above those of traditional varieties. Studies in Guinea and Sierra Leone found significant increases in farm household income in both countries as a result of the adoption of these improved varieties.

An evaluation of potato research conducted within the East African potato network found a high (93 percent) rate of return on this research. (See box, "Farmers Are Adopting Potato Technology.")

In addition to the evidence provided by rate of return studies, a recent study of *Maize Research Impact in Africa: The Obscured Revolution* provided evidence of more far-reaching impacts of new maize technologies. In addition to increases in yield and production, TDT also played a significant role in preventing output losses. Research on maize incorporated tolerance to selected pests and diseases, and provided new approaches to soil fertility. An evaluation of the impact of maize TDT finds that preventing the deterioration that would have occurred without TDT increased maize output by nearly 10 million tons, which translates into a 1.3 percent increase in gross agricultural product in the six countries studied.

Biocontrol for Africa

The effective use of wasps to control cassava mealy bug has been the most dramatic success of biocontrol technologies in Africa. New technologies are underway that hold additional promise for cassava, as well as for other African crops.

Natural enemies of the cassava green mite, predaceous mites from Brazil, have been successfully established in Africa through releases in Kenya, Ghana, Burundi, and Benin. The cassava green mite is being kept under control in these areas. New releases are being made with national programs in other ecological zones.

Biocontrol has also been successful in controlling the mango mealy bug, using the national biological control centers and manpower developed to control the cassava mealy bug. Releases of natural enemies from Côte d'Ivoire to Zaire has been generally successful. A new parasitoid from India is being tested in areas where earlier releases were not completely successful.

Additional biocontrol research is underway. A project to develop microbial control for locusts and grasshoppers, begun in 1990, has achieved some promising results. Several promising fungi have been identified and are being tested for pathogenicity. Efforts are also underway to develop biocontrol programs for cowpeas (bean flower thrips) and maize (maize stem and cob borers).

Farmers Are Adopting Potato Technology

Potato research has developed a collection of cultivars that are more disease and insect resistant than traditional varieties. Cultivars have been widely disseminated throughout the region. Farmers in Rwanda, Burundi, Uganda, and Zaire have rapidly moved to adopt these varieties, abandoning traditional varieties that did not perform as well.

The results of disseminating this improved technology are dramatic. In Burundi and Rwanda, 88 to 90 percent of farmers grew the most popular improved varieties (Ndinamagara, Sangema). In Uganda and Zaire, 56 to 59 percent grew the most popular improved varieties (Cruza).

Farmers have been willing to abandon older varieties as improved cultivars become available. Surveys in Burundi, Rwanda, and Zaire found farmers had abandoned 24 to 40 varieties in favor of improved cultivars. Farmers were also willing to substitute improved varieties for newer improved varieties as research produced and disseminated them.

2.2. Markets Matter

Successful technology adoption occurs when there are functioning markets into which increased output can be sold. Markets can be local, national, or international. Where well functioning input and credit markets exist, new technologies can generate increased employment and income in both the agricultural and nonagricultural sector. Greater attention needs to be paid to understanding cross-market linkages, to improving market operations, and to developing more effective ways of linking market demands to research and technology development.

Several successful cases of TDT demonstrate the importance of markets. They also demonstrate that there are a number of ways to achieve supportive market systems, including supportive government programs and organizations, private sector competition, and the operation of informal markets.

The development of cotton production in the Sahel depended critically on the export market and the government's willingness to

pass export gains back to producers. Government programs also created effectively functioning input and credit markets. However, macroeconomic changes, especially the overvaluation of the CFA franc, made many of these gains difficult to sustain in the 1990s.

The adoption of new maize varieties has also been tied to effective markets. Commercial markets for maize in Kenya and Zimbabwe provided outlets for increased production. Relatively well functioning input markets for seed and fertilizer also facilitated technological adaption. In Nigeria, new maize varieties were adopted largely in response to market opportunities in nonmaize growing areas (e.g., the south). The growth of cash markets provided farmers with returns that made it possible to invest in the cash inputs needed to adopt the new technology.

New technologies, which dramatically increased yields of potatoes and beans in Rwanda were facilitated by the existence of local markets for these crops, as well as a vibrant informal regional market.

Conversely, poorly functioning input or output markets have been associated with a litany of failures. They frustrated the adoption of improved varieties of several subsistence crops such as sorghum and millet that required purchased inputs to achieve increased yields. Market distortions also limited the adoption of new oilseed varieties in Uganda.

2.3. Technologies Exist—But Not Enough

Available technologies can increase agricultural productivity significantly and can be adopted by producers, marketing agents, and processors in response to changing economic conditions and emerging market opportunities. However, these technologies do not address all key constraints, and they apply to differing time frames. In some crucial areas, for example environmental management and sustainability, sustainable technologies are expected to make their major impact in the first decade of the 21st century. Thus, continued investment in TDT is essential.

There are currently a set of technologies available or under testing that could have substantial impacts within this decade.

IITA has identified a collection of sustainable plant health management technologies for maize that are currently under testing and development, including maize varieties with increased resistance to maize streak virus and stem borer, as well as on-farm testing of disease resistant cowpea varieties. It is also investigating biocontrol programs for the larger grain borer (a major threat to stored maize) and bean flower thrips (a major constraint to cowpea production).

There are also new maize technologies on the horizon. There continue to be releases of improved maize varieties, both hybrid and open pollinated varieties, for subtropical, midaltitude, and highland areas. Improved varieties will continue to increase productivity and production. The recent development and release of a high yielding flint maize variety will significantly increase maize production in Malawi, where it is apparently being rapidly adopted. Improved cropping patterns are currently being developed by Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) for late planted maize, maize in drier areas, and striga control. Current research also involves improving soil fertility in maize-dominated cropping systems.

New rice technologies also show promise for increases this decade, including varieties with increased tolerance for salinity, cold, and iron toxicity. (See box, “New Rice Technologies.”

Recent breakthroughs in understanding the basis of the host plant-striga interaction has holds promise for the development of striga resistant varieties. Researchers at Purdue University identified the chemical that, when released by the host plant, stimulates striga germination. When this chemical is not produced,

New Rice Technologies

Agricultural research is developing streams of new technologies for virtually all the major rice environments in West Africa. These technologies promise to dramatically increase rice production, at the same time providing better management of the environment and increased sustainability.

More than three-quarters of West African rice is produced in a continuum (lowland-upland) environment. New technologies could increase production by 32 percent or 1.07 million tons per annum. Technology development has two thrusts: selecting and developing varieties with disease, drought, or toxicity tolerance (1994–97); and developing sustainable, environmentally sound, management systems (1998).

1994

- Selection of *upland* varieties with moderate blast and drought resistance.
- Selection of *lowland* varieties with moderate tolerance to iron toxicity.
- Selection of *rainfed and irrigated lowland* varieties resistant to the African gall midge.

1995

- Development of *rainfed and irrigated lowland* varieties tolerant of waterlogged and submerged conditions.
- Development of *rainfed and irrigated lowland* varieties tolerant to iron toxicity.

1996

- Develop drought resistant *upland* varieties with improved weed competitiveness for low input management
- Develop *upland* varieties adapted to acidity, aluminum and manganese toxicities, and phosphorus and nitrogen deficiencies in the *humid zone*.

1997

- Development of *lowland and upland* varieties with durable rice blast disease resistance.
- Development of *upland* varieties resistant to stem borers.

1998

- Development of low cost integrated weed management systems for *upland* rice.
- Development of low cost integrated weed management systems for *lowland* rice.
- Development of multiple crossing systems for *inland valleys* with lost cost water and soil fertility management practices.
- Development of management systems to arrest and reverse soil fertility declines in *upland* soils intensively cultivated under low input management.

or is produced at a very low level, striga seeds will not germinate. Methods for screening the level of this chemical have been developed, and the mechanism for its inheritance determined. Sorghum varieties with this trait are now being field tested.

In addition, other technologies are currently being developed that may aid sustainable development efforts by the first decade of the 21st century. These include a major effort by IITA to develop microbial controls for pest, diseases, and weeds to complement biocontrol programs; and the development of low-cost integrated weed and soil fertility management systems for rice.

Despite these technologies, however, scientists have identified several areas in which development was lacking, and additional effort was required to generate new technologies. These include insect/host plant resistance, fun-

gal resistance genes, and technologies for sustaining soil fertility.

2.4. Institutions in Crisis

At a time when it is both important and promising to push for the development and dissemination of technologies to support sustainable growth, the research institutions that must be the bedrock for any such initiative are themselves in a state of crisis.

African research systems have had a slow rate of technology generation in the NARS and slow adoption by African farmers. The workshop identified several generic constraints to improved performance:

- obsolete public statutes and procedures that limit the creation of an enabling research environment and inhibit the development of a flexible system;
- donor procedures that do not give real control to Africans;
- lack of mechanisms to integrate agricultural sector actors into the TDT process;
- the inability of weak and fragile financial management systems to assist researchers in meeting challenges; and
- ineffective efforts to link research with market opportunities and development challenges.

The challenge for the NARS, as one workshop participant put it, is to take the system out of its "intellectual ghetto" by making it more demand driven and accountable *and* more productive and sustainable. Developing effective, sustainable agricultural research system is the major challenge for Africans, the donors, and the international agricultural research centers (IARCs). TDT must be viewed in a systems context, both within countries (links between NARS, universities, and the private sector) and internationally (links between NARS, regional research systems, and the IARCs).

There is general consensus that serious attention must be paid to setting priorities for research work, and assuring sustainable funding for the high priority areas. There is also general consensus that management systems should be revised to introduce accountability and transparency at all levels of the research system.

3. Designing Research Systems for the 21st Century

3.1. Challenge

One of the workshop participants stated the challenge succinctly: "We must avoid the trap of using hindsight to redesign or fine tune the research institutions we wish we had had in the 1970s and the 1980s." The world is changing in fundamental ways, and there are new challenges that deserve attention in the design of agricultural research institutes.

3.2. Demand Driven

One major challenge is to make research systems more demand driven, enabling them to respond to market demands with profitable and sustainable technologies that support economic development. Demand-driven systems require openness to diverse interests in the agricultural system (e.g., farmers, the private sector, and universities) and the capacity to maintain continuity while integrating new research thrusts into the research agenda.

Demand-driven systems should respond to market realities and opportunities. In many countries economic reform has stimulated the development of private enterprise and created market opportunities that did not exist a few years ago. Demand is less constrained by artificial policies. Research systems need to be effectively linked into market developments, and focus their energies on commodities for which there is high, growing demand, and on portions of the overall food system where technological innovation has the highest payoff for growth and employment. The technology systems need to be able to respond to producer and consumer demands for products.

The commodity systems approach can be used as a tool to examine the full range of transactions from the farmer to the consumer. By looking at the commodity system as a whole, it is possible to identify crucial bottlenecks to increased growth. Frequently these occur not at the farm level but in the transportation or processing area. Research focused on producing technologies that address these constraints would have a high payoff for economic growth. Commodity systems research has proven effective in identifying constraints in several recent cases. It facilitates vertical integration of the system thereby strengthening demand linkages. It does not, however, replace the horizontal integration at the farm level, as emphasized in farming systems research.

Commodity system approaches are not a panacea. There are research issues that are not commodity specific, including importantly, environmental and sustainability issues. A broader examination of farming systems in ecoregions is often needed. Such approaches are currently being developed in the Consultative Group for International Agricultural Research (CGIAR) system.

In addition, not all demands come from the marketplace. Demands for more environmentally sustainable technologies often come from a variety of sources. In many cases, where the costs of environmental damage are not reflected in the market, market signals will not reflect the social demand for improved resource management. Policy changes, as well as the positions of local communities, are an important component of demand in such instances.

3.3. Increasing Pluralism in Development by Reaching a More Diverse Clientele

A demand driven, responsive research system needs to have effective linkages with a wide range of groups within society. Many research systems have been heavily focused on academic research, and have not developed strong linkages to domestic groups. Where such links have been sought, they have been primarily links to producers. The workshop concluded that increased pluralism included both the focus on developing links to the private sector, and increasing the range of social groups with which interaction occurs. For example, an effort must be made to include women, a group that accounts for a substantial share of both production and local marketing. Linkages should also be developed with nongovernmental organization (NGOs).

In other instances, research institutes have missed the opportunity to work with groups whose stewardship of technologies is needed to make transfer and adoption work. Better links to seed multiplication facilities, input suppliers and manufacturers during the research process would make researchers more capable of addressing transfer issues directly.

In sum, a broader clientele is likely to be an effective prerequisite for sustainable national funding.

3.4. Balance Between Productivity and Conservation

Research systems must create new capabilities to develop and disseminate technologies to support environmental sustainability. The challenge here is to develop new technologies that meet market demands in ways that are environmentally sustainable. Work of this type already begun in many developed countries. For example, the Agricultural Research Service of the Department of Agriculture has had considerable success in its program to develop new environmentally friendly uses for agricultural commodities. This line of research is relatively limited in Africa, however.

The need for environmentally sustainable technologies arises from environmental conditions or problems, rather than from current market demand. Indeed, environmental policies and regulations typically emerge in cases where market signals do not accurately reflect social costs and benefits. Technologies that help sustain productive environments may require research in heterogeneous agroclimatic zones and the involvement of a wide range of local institutions in dissemination. There is a general consensus emerging among IARCs and donors that research should be done along ecoregional lines and that research should be look at in holistic approaches. There is also a consensus that more sustained effort is needed in this area.

3.5. Regionalization

Research systems must also establish the effective regional cooperation to support more liberal, environmentally focused research institutions. Regionalization will entail not only more attention to ecoregional zones, but also the development of management and decision making mechanisms that support regional research and link these programs back to the work of both NARS, IARCs, and the universities. It is also crucial to effectively link African research systems into the rapidly changing global research network, including links to new research areas such as biotechnology.

There is an emerging consensus on key features of new regional collaboration.

- national systems are the lead force in regional programs;
- regional programs take account of comparative advantage within the NARS;
- national systems should have financial and management responsibility for regional pro-

grams/regional networks; and

- more effective collaboration between NARS and IARCs in regional programs.

Some countries have already begun to prioritize their national research efforts regionally. In the Sahel, national systems have agreed to avoid duplication in their programs by establishing regional priorities, and assigning responsibility for priority research programs to specific countries (e.g., Mali for sorghum, Senegal for small ruminants, and Burkina Faso for natural resource management). Regionalization permits countries to downsize less crucial programs in these areas and free up resources for other uses.

Efforts are also underway to develop new modes for the transfer of leadership and financial responsibilities to African agencies. The World Bank has worked with the Northern European and Southern African countries to establish a regional gene bank. The gene bank will be managed by Africans. All staff will be Southern African as well. Working with the Northern Europeans (who currently fund it), the Bank has developed a plan under which the Northern Europeans will fund all costs (including recurrent costs) for ten years, with member states assuming increasing responsibility for funding over the next ten years. At the end of the 20-year period, funding would be provided completely by member states.

Mechanisms to develop and maintain broader linkages need to be created. One possibility is to create a council of NARS leaders, and establish regular consultative meetings of this group. The input from this group should, in turn, weigh heavily on the regional activities of IARCs, as well as the assistance plans of donors.

It is particularly important for donors to be respectful of research priorities established at the national and regional levels. A number of seminar participants noted that while donors advocate a process of priority setting, they tend to simultaneously pursue their own research activities. Sometimes, these efforts conflict with national research priorities. Greater linkages and coordination among NARS and donors is needed to avoid such outcomes.

As national research institutes develop their priorities, they should do so with a better understanding of the capabilities and activities of other research institutions. Linkages among research institutes can prevent duplication of effort in key areas, as well as provide the basis for more effective national planning. In addition, shared priorities can provide the basis for identifying regional priorities, which could be supported and/or undertaken by a variety of countries with interest in particular research areas (see section 5.3).

3.6. Identifying New Technology Needs

African research systems will need to pay increasing attention to identifying new technological needs and to the economic and environmental forces that transform African agricultural systems.

One force generating new technological needs is the transformation of African agriculture. As African agriculture makes the transition from a relatively unintegrated system to a more integrated commercial system, it will be important to identify new technologies that will support or catalyze this transformation. While some of these technological needs relate directly to production, others occur elsewhere in the food system. Storage, transportation, processing and packaging are all examples of related areas that require TDT suppport. Commodity systems analysis may be useful in identifying major constraints or bottlenecks that could be addressed by the development and transfer of new technologies.

Part of the effort to identify new technology needs can be linked to the importance of assessing the technological frontier as it currently exists in sub-Saharan Africa today. What are the current technologies available for appli-

cation? What technologies are under development for technology transfer if key bottlenecks are to be broken? There may be tradeoffs between national systems having the capacity to develop technologies versus focusing on developing contacts and validating technologies in new areas.

Enhanced linkages between public sector research institutions and the private sector, both domestically and internationally, will be important to identifying existing technological frontiers, as well as strategies for transferring and/or commercializing high potential technologies.

Finally, new technological needs identified with conservation and sustainability in mind will be required to meet food needs, especially in population-driven areas where resource constraints are already a serious problem.

4. Creating an Enabling Environment for Sustainable Research Systems

4.1. Challenge

Donors have invested heavily in developing the human capital for national research systems. These investments have succeeded in creating a larger cadre of trained researchers who often return to institutions that are unable to effectively utilize their skills. Over the next decade, we must develop a sustainable financial and institutional base to support the investments in human capital made over the last decade.

4.2. Reforming Research and Policy Institutions

The NARS are the building blocks for sustainable research systems in Africa, but they face constraints such as weak financial management systems, obsolete public statutes and difficulties linking research with market and development challenges. An emerging consensus among Africans and donors suggests that creating a more enabling environment must include the revitalization of the NARS and the development of new, effective modes of regional cooperation. Both institutional reform and regional cooperation are key elements of the Special Program for African Agricultural Research (SPAAR).

There was a general consensus that over the next decade, Africans should take the leadership for the NARS and regional research initiatives. At the same time, there should be greater transparency and accountability throughout the research system.

There is also an emerging consensus of the key components of the institutional reform agenda. These include:

- creating systems to establish research priorities (see section 4.2);
- developing programming and funding mechanisms to support these priorities;
- developing personnel and management systems committed to retaining a motivated core of quality scientists;
- establishing greater management autonomy, transparency and accountability;
- creating sustainable financing arrangements;
- restructuring incentives to make scientists and scientific teams accountable for relevant output; and
- promoting institutional pluralism.

Several African countries, including Mali, Tanzania, Uganda, Rwanda and Gambia are presently implementing programs for institutional reform.

4.3. Priority Setting

Mechanisms for priority setting must be improved. Priority setting involves both decisions about the relative payoff of alternative research approaches and about the mandate of public research institutions.

Issues related to the purpose and mandate of public research institutions are likely to reflect political responses to pressing social and economic issues. National economic and social priorities must be reflected in the workplans of publicly funded institutions. The issue is how to incorporate these in a way that facilitates both the achievement of national goals and the development of more efficient, sustainable national institutions.

The prevailing top-down model for priority

setting seeks direction on priorities from national policymakers. A number of participants, some engaged in priority setting activities found it difficult to obtain clear signals on priorities. Policy dialog may be important in helping policymakers see the importance of research, helping them understand the importance of focusing research on problem areas where it can make a contribution, and pointing out the opportunity costs involved in suboptimal allocations of research funds. Stronger efforts by national research institutions to publicize the results of agricultural research, and its importance to future development, would also be helpful. More direct contacts between research institutions and other groups might also be effective in determining what issues are of high priority to potential outside users.

Disagreements among workshop participants on the proper function of public research institutions caused several participants stressing the importance of resolving such issues in Africa through a broad-based process.

Progress can be made in setting institutional priorities without this wider deliberation, however. Experience suggests that a comprehensive review of the quality, coherence and impact of existing programs can provide the basis for improved priorities and performance. In Burundi, for example, a comprehensive review of programs and their impact identified a wide range of problems—including not only duplication and lack of focus, but also ineffective and inefficient programs—that could be addressed by restructuring the institution and consolidating resources around programs with proven effectiveness.

4.3.1. Principles / Methods for Priority Setting

Priority setting is not a mechanical process. Priorities need to reflect the potential impacts or gains from research in certain areas, the scientific feasibility of research areas, the scientific likelihood of achieving a breakthrough, and the socioeconomic priorities of governments and key research clientele. Nevertheless, there are some basic principles that can be applied to priority setting, and several approaches that can support the application of these principles.

4.3.2. Commodities and Cross-Commodity Themes

Select as priorities topics, commodities and cross-commodity themes in the regional and national context that support agricultural transformation and sustainable growth.

Demand analysis: A focus on demand-driven research systems can assist in priority setting. Past attempts to set research priorities have often proceeded from relatively simplistic criteria, such as the acreage planted to particular crops, the value of commodity production, or the number of scientists working in a particular commodity area. Demand-driven analysis can identify commodities for which demand is likely to increase, or which are most central to increasing the income of farmers, or making a contribution to overall economic development. Such criteria are less arbitrary, and provide for some attempts to estimate the expected benefits from research in these areas.

4.3.3. Key Constraints

Focus on eliminating binding constraints (production, marketing, and processing) within a subsector or noncommodity theme.

It is also important to identify key constraints to increased performance in a commodity system, and make removing such constraints a relatively high priority.

4.3.4. Impact

Support technologies that can have high impacts on incomes, food security, and environmental sustainability.

Impact analysis: Impact analysis can make a major contribution to priority setting. At-

tempts to develop measures of impact can identify areas in which research resources will likely make the greatest impact on overall economic growth. It can similarly identify ineffective research and technology activities. In addition, impact analysis can be used to monitor progress in both research and technology transfer. In combination with clear performance and accomplishment priorities, such monitoring can make it easier to focus resources, and to avoid prolonged investment in activities that are not producing results.

4.3.5. Feasibility

Identify priorities that are scientifically achievable within the resource base of the institutions undertaking them.

Scientific analysis: Research priorities cannot be set without a sound analysis of their scientific achievability. Some areas in which there is a strong demand for technology may be scientifically difficult, or beyond the capabilities and resources of the existing research system. In addition, scientists have an independent contribution to make in identifying research areas that hold the potential for significantly increasing understanding which can, if successful, open new research capabilities with broad application to the agricultural system. The scientific and economic importance of research must be weighed in setting research and technology priorities.

4.4. Management and Accountability

New management systems should be established for "results oriented" research and technological activities. At the level of the researcher, this translates into clear standards for performance, weighted on producing impacts on the productivity and growth of the agricultural sector, rather than simply on the publication of research papers. Individual researchers would have a broader responsibility for "making things happen," which might imply closer coordination with farmers, private sector organizations or stewardship institutions. Resources should be allocated to research activities based upon their ability to show results.

Management would be held accountable for establishing efficient and effective systems for generating and using resources. This would include not only the establishment of clear priorities, but continued monitoring of progress and adjustments of resource allocations based upon feedback on performance.

4.5. Creating Financially Sustainable Funding Mechanisms

Sustainable research institutions must ultimately be able to generate support from national governments, institutional clientele, and where appropriate, the private sector. Some examples of innovative funding arrangements currently exist (e.g., joint venture research between public and private sector organizations in Zimbabwe). (See box, "Contract Research in Zimbabwe.")

African systems have not had much national public funding. One participant identified the reasons for this: the agricultural sector is often not high priority and scientists do not do a good job of publicizing research's importance and results.

Major effort to establish more sustainable funding system are being addressed under the SPAAR initiative. Effort recognizes the need to increase national funding, but also the reality that donor funding is a key component of the current system, and may in some instances contribute to the proliferation of research activities.

SPAAR's consolidated funding and budgeting mechanism seeks to tie institutional reforms with new funding arrangements that will support the new institutional structure. Key components of the system include: donor funding to cover overhead costs—the variable indirect costs of programs; creating an agricultural

research fund to take multifunded sources and multipurpose use; and a method for establishing "core funding" for the NARS. Core funding might develop along the lines currently used in the IARC system, under some kind of technical advisory committee (TAC). World Bank can now fund recurrent costs that are not incremental and not related to foreign costs; 4 to 5 other donors can do the same.

In addition, however, there are funding mechanisms used in other countries that have not been extensively explored in the African context. The workshop presented five alternative funding models. These include:

1) *Public appropriated funding:* with or without matching requirements. Funding can be allocated in various ways, including: formula funding, competitive grants, and legislative earmarks.
2) *Checkoff systems:* a private sector activity where producers voluntarily contribute receipts at the first point of sale. Proceeds need not be used only for research.
3) *Debt for research conversions:* external and internal institutions agree on a project. The external institution uses hard currency to buy discounted debt, sells the debt to the central bank for soft currency, which is used to fund research.
4) *Development foundations:* these institutions can accept "lumpy" contributions from internal and external donors, which can then be used to fund high priority projects from scientific institutions, smooth out variations in funding, and invest in an inflation-proof portfolio.
5) *Commercialization of technology and products resulting from research and development:* Patent rights can be sold or leased to private firms as a means of generating sustained funding for the research and development institution as well as the inventor.

One speaker evaluated these nontraditional funding sources in Africa using the categoriza-

Table 1. Categorization of Funding Alternatives for Agricultural Research with Selected Criteria

	ALTERNATIVE					
CRITERIA	Public, appropriated funds for institutions	Public appropriated funds for competitive grants	Check-off programs	Debt for Research Conversions	Development Foundations	R&D plus Commercialization
Ability to pay	+ + +	+ + +	+ +	+ +	+ +	+ +
Benefits received	+ + +	+ + +	+ +	+ +	+	+ +
Ease of administration	+ + +	+ +	+ +	+	+ +	+
Dependability	+ +	+ +	+ +	+ + +	+ + +	+

+++ = high potential; ++ = medium potential; + = low potential

Contract Research in Zimbabwe

Zimbabwe has developed an effective, innovative approach to contract research that has produced and disseminated relevant agricultural technology. The Agricultural Research Trust (ART) was established in 1982. It is funded by commercial farmers and the agricultural trade. Research is conducted on its own central farm outside Harare. ART covers its annual operating costs from the interest on its initial trust ($1.8 million), annual production levies (raised by the commodity associations), and fees for contract research undertaken for others. Its researchers are paid competitive salaries and have the equipment needed to conduct effective research.

Trials have been conducted on all major field crops and some horticultural crops. Cost-saving and yield-enhancing technologies have been developed, swiftly disseminated, and adopted. ART also puts its latest developments into practice in its own commercial farming operation, thus hoping to bridge the gap between research station results from experimental plots and the results that farmers actually achieve.

tion scheme depicated in table 1. Additional funding mechanisms that could be tied to the commercialization of technologies are discussed in section 5.2.

4.6. Developing and Sustaining Human Resource Capacity

African research institutions can make substantial gains in developing and sustaining their human resource capacity. When achievable priorities have been set, researchers should receive adequate remuneration to keep them within the research institutions.

In addition, incentive systems should reward both research achievement and entrepreneurial skill.

5. Commercialization and Transfer of Technology

5.1. Challenge

We need to make TDT more results-oriented so that researchers (public and private) have incentives and mechanisms to transfer profitable and sustainable technologies. Establishing new incentives involves altering institutional norms and legal practices to facilitate commercialization. For example, researchers should be rewarded for the impact of their technology rather than for the production of results. It is also important to assure that TDT systems operate at or near current technological frontiers in Africa. Finally, public and private interests must collaborate if the commercialization and transfer of technology is to succeed.

5.2. Commercializing Technologies

Developing countries have developed some mechanisms for facilitating the commercialization of technologies produced in public research programs. Several examples were presented in the workshop:

- the British Technology Group obtains and manages patents and licenses;
- the Alternative Agricultural Research and Commercialization (AARC) in the U.S. Department of Agriculture (USDA) provides "bridge" financing via grants (not equity positions), uses "transition" laboratories (e.g., veterinary medicine), and carries out research to a point where it gives a tolerable level of risk for commercialization to the private sector; and
- the Federal Technology Transfer Act (United States) allows industry to participate in research from the beginning. A private company invested in the work via a Cooperative Research and Development Agreement); an industrial company gets exclusive rights to results of research. A scientist gets 15 to 25 percent of royalties (up to $100,000/year). This program has a large "green portfolio"—biological control and environmentally friendly products—for which there is market demand.

5.3. Increasing Private Sector / NGO Collaboration

Workshop participants pointed out the importance of increasing the involvement of NGOs and private and public sector institutions in the dissemination of technologies and information. It was also noted, however, that successful public-private collaboration must understand differences between public and private orientations toward research and technology. Private firms seek to develop proprietary products, have more secrecy in research programs, and may initiate research activities that parallel those of competitors in order to maintain or increase market share.

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Annex 2

List of Presentations / Papers

Presenter / Affiliation	Title(s)
Jerry Wolgin / USAID/AFR/SD	"The Strategic Framework: A Paradigm Shift"
John Staatz / MSU	"The Role of Agricultural Technology Transfer in Agricultural Transformation in Sustainable Development"
Jim Oehmke / MSU	"The Impact of Investment in Agricultural Technology Transfer and Development in Sub-Saharan Africa"
Jeff Hill / USAID/AFR/SD/ PSGE	"The Technology Transfer and Development Analytic Agenda"
Richard Bernstein / MSU	"Subsector Development and Analysis"
Ellen Freud / CIRAD	"Economic / Technological Factors Influencing Regional Research Priorities of the Humid and Subhumid Zones of West and Central Africa"
Dirck Stryker / AIRD	"Demand Analysis—Output and Input Markets"
Elon Gilbert / consultant	"Prospects for the Development and Transfer of Maize Related Technologies in Africa: Lessons from Experiences"
Delbert Hess / CIMMYT	"Recent Developments in Maize Technology"
George Weber / IITA	"Recent Developments in Maize Technology"
Peter Ewell / CIP	"Recent Developments in Potato and Sweet Potato Technology"
Peter Mation / WARDA	"Recent Developments in Rice Technology"
John Axtell / Purdue University	"Recent Developments in Millet and Sorghum Technology"
Balu Bumb / IFDC	"Fertilizer Policy in Soil Fertility and Soil Restoration"
Bill Fiebig / DESFIL	"Natural Resource Management Technologies"
Hans Herm / IITA	"Biocontrol Technologies"

Russell Freed / Bean/Cowpea CRSP	"Input Use and Soil Fertility"
Eric Crawford / MSU	"Constraints to the Development / Use of Improved Technology"
John Sanders / Purdue University	"Technology Development for Semi-Arid Sub-Saharan Africa: Theory, Performance, and Constraints"
Jeff Hill / USAID/AFR/SD/ PSGE	"TDT Analytical Agenda for Institutional Reform"
Moctar Toure / SPAAR M. S. Sompo-Ceesay / INSAH Andrew Spurling / World Bank	"Institutional Reform in African Agricultural Research Systems"
Howard Elliot / ISNAR	"Priority Setting in Sub-Saharan African National Agricultural Research Systems"
Jim Oehmke / MSU	"Incorporating Demand and Impact Analysis into Priority Setting"
John Sanders / Purdue University William Masters / Purdue University	"Impact Assessment in a Regional Contect"
Tom Whitney / USAID/Burundi	"Country Experience with Priority Setting: Burundi"
B. W. Ngundo / KARI	"Introduction to Priority Setting" "Research Priorities and Programmes in Crops and Livestock in Kenya National Agricultural Research Project (NARP) of the Kenya Agricultural Research Institute (KARI)" "Linkages Between Priority Setting, Resource Allocation, and Impact Assessment: The KARI Experience"
Andrew Spurling / World Bank	"Consolidated Funding and Budgeting Mechanism" "Zimbabwe—The Agricultural Research Trust and Contract Research"
Melvin Blase / University of Missouri	"Funding Mechanisms for Agricultural Research"
Ruxton Villet / USDA/ARS	"Legislative Mandates for Technology Transfer: Experience with the U.S. Technology Transfer Act"